

Attorney Docket No. 82856  
Customer No. 23523

FREE ROTATING INTEGRATED MOTOR PROPULSOR

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT THOMAS J. GIESEKE, citizen of the United States of America, employee of the United States Government, a resident of Newport, County of Newport, State of Rhode Island, has invented certain new and useful improvements entitled as set forth above of which the following is a specification.

JAMES M. KASISCHKE, ESQ.  
Reg. No. 36562  
Naval Undersea Warfare Center  
Division Newport  
Newport, RI 02841-1708  
TEL: 401-832-4736  
FAX: 401-832-1231

1 Attorney Docket No. 82856

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3 FREE ROTATING INTEGRATED MOTOR PROPULSOR  
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5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used  
7 by or for the Government of the United States of America for  
8 governmental purposes without the payment of any royalties  
9 thereon or therefor.  
10

11 BACKGROUND OF THE PRESENT INVENTION

12 (1) Field of the Invention

13 The present invention relates to an integrated motor  
14 propulsor comprising a free rotating duct assembly. More  
15 specifically, the present invention relates to a free rotating  
16 duct assembly incorporating a stator and outboard blades to  
17 provide counter-torque rotation about a plurality of rotor  
18 blades.

19 (2) Description of the Prior Art

20 The Integrated Motor Propulsor (IMP) is a propulsor design  
21 concept which integrates an electric motor with the moving parts  
22 of a ducted propeller. With reference to FIG. 1, there is  
23 illustrated a cross sectional rendering of the basic concept of  
24 an IMP 10. The centerline of an underwater vehicle is identified  
25 as 12 and the mouth of the ducted propeller is identified as 14.  
26 The rotor blades 16 of the propulsor act as the rotors of the  
27 motor while the stator 18 is housed in a duct assembly 20

1 encapsulating and encircling the rotor blades 16 about center  
2 line 12. In the IMP design of FIG. 1, permanent magnets 21 are  
3 positioned on the outside of rotor blades 16.

4 This propulsor design is ideal for isolating the propulsor  
5 10 from the main vehicle body 22 and can provide high efficiency.  
6 The IMP 10 requires large physical duct supports 24 tying the  
7 duct assembly 20 to the vehicle body 22. Electrical current is  
8 provided from the vehicle to the stator 18 via an electrical  
9 connection 26 extending through support 24. These physical duct  
10 supports 24 on the IMP 10 are required to hold the duct assembly  
11 20 stationary while large torques are applied to the rotor blades  
12 16 as they spin about center line 12 under a load.

13 Although it is possible to engineer suitably large physical  
14 duct supports 24 to properly constrain the duct assembly 20, the  
15 hydroacoustic impact of having large struts upstream or  
16 downstream of the propulsor 10 can be significant. Blade rate  
17 tonals are produced when the disturbances from the rotor blades  
18 16 periodically impact the duct supports 24.

19 What is therefore needed is an IMP design concept that  
20 eliminates the duct supports.

21

## 22 SUMMARY OF THE INVENTION

23 Accordingly, it is an object of the present invention to  
24 provide a free rotating duct assembly incorporating a stator and  
25 outboard blades to provide counter-torque rotation about a  
26 plurality of rotor blades.

1        In accordance with the present invention, an integrated  
2 motor propulsor includes a rotor having a plurality of rotor  
3 blades adapted to rotate about a center axis. Each of the  
4 plurality of rotor blades radially extends in a direction from  
5 the center axis to a terminus. A circular outer ring is in  
6 contact with the terminus of one of the rotor blades. A duct  
7 assembly is circumferentially disposed about the circular outer  
8 ring and in low friction contact with the circular outer ring.  
9 The duct assembly has a plurality of stators encircling the outer  
10 ring, and a plurality of outboard blades extending radially from  
11 the duct assembly. Each outboard blade is attached to a pitch  
12 control apparatus located in the duct.

#### 14                    BRIEF DESCRIPTION OF THE DRAWINGS

15        FIG. 1 provides a cross sectional illustration of an  
16 integrated motor propulsor known in the art.

17        FIG. 2 provides a cross sectional illustration of an  
18 integrated motor propulsor (IMP) of the present invention.

#### 20                    DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

21        With reference to FIG. 2, there is illustrated the free  
22 rotating IMP 30 of the present invention. In place of duct  
23 supports 24, a set of outboard blades 32 is attached on the  
24 outside of a duct assembly 34. Duct assembly 34 encircles the  
25 outermost periphery of a plurality of rotor blades 36. Each  
26 outboard blade 32 is pivotally attached to the duct assembly 34  
27 by a pitch control apparatus 38. This pitch control apparatus 38

1 can be an articulation motor or the like. This allows the  
2 outboard blade 32 to operate as a variable pitch propeller. The  
3 detailed function of these components is described as follows.

4 The rotor blades 36 connect the duct assembly 34 to the  
5 vehicle body 22 defining a duct 40. In a preferred embodiment,  
6 an outer ring 42 connects, in circular form, the outermost  
7 portions of the rotor blades 36 and is in low friction contact  
8 with an inner surface 44 of duct assembly 34. By "low friction  
9 contact" it is meant contact with sufficient clearance to enable  
10 the free rotational movement of the duct assembly 34 about the  
11 rotor blades 36. One preferred form of low friction contact  
12 involves the circumferential distribution of ball bearings 45  
13 about outer ring 27 and in contact with inner surface 29.

14 A stator 46 is positioned on inner surface 44 where it can  
15 interact magnetically with permanent magnets 47 positioned in  
16 outer ring 42. Obviously, another magnetic field generating  
17 component could replace these permanent magnets. This component  
18 could be an electromagnet, induction coil or the like.

19 Rotor blades 36 serve several purposes. They act as the  
20 rotors in the electric motor. In addition, rotor blades 36 hold  
21 the duct assembly 34, and therefore the attached outboard blades  
22 32, in connection to the vehicle body 22 via the outer ring 42.  
23 At least one of rotor blades 36 is hollow and is therefore  
24 configured to serve as a conduit for all electrical connections  
25 48 to the stator 46, pitch control apparatus 38, and sensors 50  
26 which can be mounted on the duct assembly 34. Examples of such  
27 sensors 50 include, but are not limited to, sensors 50 to measure

1 the absolute and relative speed of the rotational motion of the  
2 stator 46 and rotor blades 36, velocity of flow across the  
3 surface of the duct assembly 34, and environmental pressure  
4 measurements.

5 Provision of power to stator 46 and communication with the  
6 sensors 50 is achieved by using an inner slip ring 52 and an  
7 outer slip ring 54. The inner slip ring 52 allows electrical  
8 communication between the rotary joint between vehicle body 22  
9 and rotor blades 36. Inner slip ring 52 is joined by electrical  
10 connection 48 to outer slip ring 54. The outer slip ring 54  
11 allows electrical communication between rotor blades 36 and  
12 pitch control apparatus 38, stator 46 and sensors 50.

13 The outboard blades 32 are each articulated with pitch  
14 control apparatus 38. Variation in the pitch of the outboard  
15 blades 32 controls the torque required to drive the outboard  
16 blade system and consequently controls the relative speed of the  
17 inboard rotor blades 36 and the outboard blades 32.

18 The outboard blades 32 are designed to provide an optimal  
19 counter-torque to drive the rotor. Absent the outboard blades 32  
20 providing such a counter-torque, the duct assembly 34 would  
21 commence to spin at a high rate counter to the direction of the  
22 rotor blades 36 and waste potential thrust in the form of  
23 unwanted rotational momentum. In addition to providing a  
24 resistance for the motor to work against to drive the rotor, the  
25 outboard blades 32 act as a second set of propeller blades.

26 In an alternative embodiment, outboard blades 32 can be  
27 fixed directly to duct assembly 34. This embodiment provides

duct assembly 34 with resistance to spinning, but it does not give the same control options as the preferred embodiment.

In operation, the free-rotating IMP functions as follows.

At startup, all motor components are stationary and the vehicle is either stationary or moving through the water. When the IMP begins to attempt to drive the rotor blades 36, the rotor blades 36 begin to spin clockwise and simultaneously the duct assembly 34 begins to spin counterclockwise (or vice versa). The rotor blades 36 begin to draw fluid through the duct 40 and drive the vehicle forward. Both the rotor and the outer blade accelerate until the torque required to drive the rotor exactly equals the torque required to drive the duct and outer blades. The relative speed of the rotor and the duct is a function of the dimensions and geometry of the rotor and the outer blades.

The pitch control apparatus 38 can be used to adjust the operation of the outboard blades 32 to increase or decrease the torque required to drive the outer blades thus changing the relative speed of the two propulsors.

It is apparent that there has been provided in accordance with the present invention free rotating duct assembly incorporating a stator and outboard blades to provide counter-torque rotation about a plurality of rotor blades which fully satisfies the objects, means, and advantages set forth previously herein. While the present invention has been described in the context of specific embodiments thereof, other alternatives, modifications, and variations will become apparent to those skilled in the art having read the foregoing description.

1 Accordingly, it is intended to embrace those alternatives,  
2 modifications, and variations as fall within the broad scope of  
3 the appended claims.